On the Line Spectra of the Elements.

PROF. STONEY seems to agree with me that I have given an obvious example of a motion for which the theorems in chapter iv. of his memoir do not hold good. Theorem B, page 591, runs thus: "Any motion of a point in space may be regarded as the co-existence and superposition of one *definite* set of partials which are the pendulous elliptic motions determined as above, &c." It is indeed obvious that a uniform motion in a straight line cannot be regarded in this manner, not even approximately for any length of time, if the set of partials are required to be *definite*. I might have given an example of a limited motion, *e.g.* $x = \sin t^2$, which equally contradicts the theorem, but I thought a more obvious example would convince Prof. Stoney more easily. I think, indeed, that the reasoning in chapter iv. of his memoir is erroneous. But I do not say that therefore Prof. Stoney's views on the cause of the line-spectra are wrong. They may be right, although the argument in chapter iv. is not. Why this criticism is not legitimate I do not see. For no slight alterations or additions would set those theorems right, as there is a palpable mathematical error at the bottom of it.

Technische Hochschule, Hanover, July 9. C. RUNGE.

The Grammar of Science.

THE exposition of the Newtonian laws as given by Thomson and Tait has unfortunately been taken as the basis for the treatment of the laws of motion by all elementary text-book writers in the English tongue since the publication of the great "Treatise on Natural Philosophy." When that exposition is attacked we are told that Newton introduced a qualifying context which has been omitted from the exposition. In other words the current statement of elementary dynamical principles is thrown overboard in favour of Newton pure and simple. On the other hand when Prof. Tait uses an expression which is totally opposed to that principle of the "subjectivity of force" which C.G.K. claims that Prof. Tait was the first, or among the first, to propound, we are told that this expression was obviously suggested by "Newton's own anthropomorphic language." C.G.K., I take it, admits that the Newtonian Laws of Motion are illogical and unphilosophical when stated by Thomson and Tait without Newton's modifying context. I propose therefore to shortly publish a criticism of the laws of motion as accompanied by that context of Newton's which does not appear in Prof. Tait's text-books. I trust C. G. K. will not then turn round on me and say, "Oh, yes, but this has nothing to do with Prof. Tait; it is Newton's own anthropomorphic language."

Lastly, as to the origin of the doctrine of the "subjectivity of force," which to my mind is just as much or as little valid as the "subjectivity of matter," I would remind C. G. K. that the first two parts of Kirchhoff's "Mechanik" were published in 1874, and were then only the publication of lectures of an earlier date. Philosophers before Kirchhoff taught the doctrine of subjectivity, but he, and not the author of the "Dynamics of a Particle," was the physicist who first helped many of us out of the mental obscurity as to dynamical principles produced by our study of the expositions of the laws of motion due to the Edinburgh school. KARL PEARSON.

"Are the Solpugidæ Poisonous?"

IN reference to this question, propounded by Mr. Bernard in your last issue, I should be inclined to answer in the negative. I captured several specimens of *Solpuga chelicornis* in the Transvaal, and on one occasion witnessed a persistent attack made on this "spider" by a bird which appeared to be the Cape wagtail (*Motacilla capensis*). Had the *Solpuga* possessed poisonous qualities the attack would probably not have been made.

The specimens taken by myself exhibited no signs of pugnacity, but always sought refuge in headlong flight to the nearest cover. W. L. DISTANT.

Russell Hill, Purley, Surrey, July 8.

Hairlessness of Terminal Phalanges in Primates.

I OBSERVE that, in your report of the proceedings of the Zoological Society, you allude to my paper on "a seemingly new diagnostic feature of the order Primates," viz. that the terminal phalanges are destitute of hair.

Since the paper was read I have found that this feature is not of ordinal value. But it is of sufficiently general occurrence to merit inquiry touching its distribution in different species.

Therefore I have withdrawn publication of the paper for the present. GEORGE J. ROMANES.

Oxford, July 1.

Mental Arithmetic.

REFERRING to the articles on "Mental Arithmetic" in NATURE, vol. xlv. p. 78 and 198, I beg to state that there also exists a very clearly written little text-book on arithmetic founded entirely on the principles mentioned by Mr. Clive Cuthbertstone. The title is "Neuer Unterricht in der Schnellrechen-Kunst," by C. Jul. Giesing, Editor, Carl Schmidt, in Doebeln (Saxony). Price 1 mark 80 pf. G. DAEHNE.

Dresden-Blasewitz, "Isis," July 9.

Jackals.

THE incident of the jackals entering Howrah brings to my memory that this winter jackals entered the suburban town of Bournabal, in the Smyrna district of Western Asia Minor. This last winter being severe, it was noticed in the papers that rabies had extended to wolves and jackals, and to this circumstance was attributed their entering the villages and attacking people, and also their attacking the domestic animals.

HYDE CLARKE.

WEIGHT.

THE following remarks are presented with the object of reducing the increasing gap which is growing between the treatment of the fundamental ideas of Dynamics, as taught in our academical text-books from the standpoint of verbal abstraction, and the ideas and language of those who have to deal with the actual phenomena of Nature as a reality.

1. According to the precise legal definitions of all our successive Acts of Parliament on "Weights and Measures," the *weight* of a body is the quantity of matter in the body, as measured out by the operation of weighing it in the scales of a correct balance.

The body to be weighed is placed in one of the scales, and is equilibrated by standard lumps of metal, stamped as pound weights, or kilogramme weights, or hundred weights, or ton weights, and the sum of these weights is called the *weight* of the body.

In the words of the Act of Parliament, 18 and 19 Victoria, c. 72, July 30, 1855, the British pound weight is defined as a weight of platinum, marked P.S., 1844, 1 lb., deposited in the Office of the Exchequer; and the Act goes on to say that this lump of metal "shall be the legal and genuine standard measure of weight, and shall be and be denominated the Imperial Standard Avoirdupois Pound, and shall be deemed to be the only standard of weight from which all other weights and all other measures having reference to weight shall be derived, computed, and ascertained, and one equal seven thousandth part of such pound avoirdupois shall be a grain, and five thousand seven hundred and sixty such grains shall be and be deemed a pound troy."

In defining the unit of length, the standard yard, the temperature must be defined, 62° F. in the Act of Parliament; but in defining the pound weight, there is in the Act no mention of temperature, height of barometer, height above sea-level, latitude, longitude, date and time of day, establishment of the port, &c., or of any other cause tending to alter the local value of g.

Details of the temperature and density of the air are only required when defining the volume of the gallon of 10 lbs. of water, or when making accurate copies of the standard platinum pound weight in some other metal—brass or iron, for instance—when a correction for the buoyancy of the air must be made; and it is to cover this detail that the words *in vacuo* have been added in the most recent Acts of Parliament on "Weights and Measures" (41 and 42 Victoria, 1878).

2. We now pass on to the investigation of the motion set up in a body of given weight due to the action of specified forces; we use the word *weight* advisedly, so as to agree with the terminology of the Acts of Parliament.

As the field of force in which we live is that due to the attraction of the Earth, it was natural to begin by taking the attraction of the Earth on our standard weight as the unit of force; and we find that in all Statical problems of architecture and engineering the unit of force employed is the force with which a pound weight, or a kilogramme weight, or a ton weight, is attracted by the Earth.

The engineer calls these forces the force of a pound, of a kilogramme, or of a ton; he does not add the word weight, reserving the word *weight* to denote the quantity of matter in the body which is acted upon, in accordance with the language of the Act of Parliament on "Weights and Measures."

In the Dynamics of bodies on the surface of the Earth, the same gravitational unit of force is universally employed in practice; and now, to take a familiar problem, we may investigate the motion of a train, weighing W tons, on a straight level railway, pulled by an engine exerting a tractive force of P tons, by the bite of the driving wheels on the rails.

Neglecting passive resistances, and the *rotary inertia* of the wheels, the train will acquire from rest a velocity v feet per second in s feet, given by

$$Ps = \frac{Wv^2}{2g} \text{ (foot-tons).}$$

The velocity growing uniformly, the average velocity will be half the final velocity v; so that if the train takes t seconds to go the first s feet,

$$s/t = \tfrac{1}{2}v,$$

and

$$Pt = \frac{Wv}{g} \text{ (second-tons).}$$

The word *second-tons* has been formed by analogy with the word *foot-tons*, to express the product of a force of P tons and t seconds, the time it acts; just as foot-tons expresses the product of a force of P tons and s feet, the distance through which it acts.

While Ps, the *work* in foot-tons done by the force P tons acting through s feet, has a mechanical equivalent, $\frac{Wv^2}{2g}$, called the *kinetic energy* of the train in foot-tons; so Pt, which we may call the *impulse* in second-tons of the force P tons acting for t seconds, has a mechanical equivalent $\frac{Wv}{g}$, the *momentum* communicated to the train in second-tons.

We merely state these theorems, with the addition of the proposed new name of *second-tons*, as these theorems are found in all dynamical treatises, being direct corollaries of Newton's Second Law of Motion.

We have measured W and P in tons, as would be natural in any railway-train problem, but the same equations of course hold when W and P are given in cwt., pounds, kilogrammes, or grammes; and then impulse or momentum will be given in second-cwt., second-pounds, second-kilogrammes or second-grammes; while work or kinetic energy will be given in foot-cwt., foot-pounds, or metre-kilogrammes, or centimetre-grammes, on changing to the metre or centimetre as metric unit of length, and changing at the same time the numerical measure of g.

3. The presence of g in the denominator of W in the dynamical equations will be remarked, and this constitutes a difficulty to the student, which our teachers of Dynamics have done their best to obscure.

The quantity g makes its appearance, not because W/g is an invariable quantity, as is generally taught, but because the unit of force in which P is measured is variable, being proportional to the local value of g.

With a foot and second as units of length and time, we may take the value of g at the equator as 32, increasing gradually to about one-289th part more, or about $\frac{1}{3}$ per cent. greater at the poles, in consequence of the Earth's rotation.

The force of a pound, meaning thereby the force with which the Earth appears to attract a pound weight, is thence about $\frac{1}{3}$ per cent. greater at the poles than at the equator; and this does not allow for the increase in g due to the ellipticity, which by Clairaut's theorem would make the total increase about $\frac{1}{2}$ per cent.

But to say that a body has gained in weight one-289th part, or $\frac{1}{3}$ per cent., in going from the equator to the pole is absurd and misleading; for if we carry our standard weights and scales with us, we shall find that the body weighs exactly the same.

When the theorist tells us that a body gains or loses one-289th part of its weight in being taken from the equator to the pole, or back again, he means that the indications on a spring balance, graduated in latitude 45° by attaching standard weights, will be about $\frac{1}{6}$ per cent. in error at the equator and at the poles.

But such a spring balance would be illegal if used according to its graduations in any other latitude than the one in which it was constructed; and the user would lose in all cases; he would lose at the equator by selling $\frac{1}{6}$ per cent. too much by weight; and he would lose at the poles the fines incurred from the Inspector of Weights and Measures, who would test his spring balance by attaching standard weights, composed of lumps of metal.

The spring balance graduated in latitude 45°, and employed alternately at the equator and the pole, is equivalent to a beam balance, of which the beam stretches over a quadrant of the meridian of the Earth from the equator to the pole, with a fulcrum in latitude 45°, but such an abnormal balance is not contemplated in the Act.

4. If we could transport ourselves to the surface of the Moon, Sun, or any planet, with our weights and scales, Newton's Law of Universal Gravitation teaches us that we should still find the body of exactly the same weight in the balance, the attraction of the Moon, Sun, or planets on the body and on the weights being still equal.

The magnitudes of these equal attractions would, however, have changed, since the attraction is proportional to the local value of g; on the surface of the Moon it is calculated that g is about 5·4; on the surface of the Sun it is about 30 times the value on the surface of the earth, while on Jupiter it is calculated that g is about 71.

These values of g are inferred from observation of the diameter of the celestial body, and from its weight, measured in terms of the weight of the Earth, or using the Earth as the standard weight; and calculated by Kepler's Third Law from the period and distance of a satellite, compared with the period and distance of our satellite, the Moon.

The weight of the Earth itself is inferred from the Cavendish Experiment, in which the attraction of gravitation between two given weights is measured.

According to Newton's Law of Universal Gravitation, the attraction between two spherical bodies, arranged in spherical strata, the Sun and Earth for instance, weighing S and E g (grammes) when their centres are a cm apart, will be proportional to SEa^{-2}; with C.G.S. units, this attraction may be expressed as CSEa^{-2} dynes, and then C is called the *constant of gravitation*; and the Cavendish experiment is devised for the purpose of measuring C.

Denoting by g the acceleration of gravity (in C.G.S.

spouds), then on the surface of the Earth we may take, in round numbers,

$$g = \mathrm{CE/R^2}, \quad \text{or } \mathrm{CE} = g\mathrm{R}^2,$$

R denoting the radius of the Earth in cm, taken as $10^9 \div \frac{1}{2}\pi$, the quadrant being 10^9 cm.

With mean density ρ, the weight of the Earth, E, in g, is given by

$$\mathrm{E} = \tfrac{4}{3}\pi\rho\mathrm{R}^3,$$

so that

$$\tfrac{4}{3}\pi\mathrm{RC}\rho = g,$$

or

$$\mathrm{C}\rho = \tfrac{3}{8}g \times 10^{-9};$$

so that ρ is known from C, and *vice versâ.*

For instance, with $\rho = 5{\cdot}5$, and $g = 981$,

$$\mathrm{C} = 10^{-8} \times 6{\cdot}688.$$

We are awaiting with great interest the quantitative results of Mr. C. V. Boys, with his improved form of apparatus; but meanwhile we may take a mean density of 5·5, the mean of Cornu's and Poynting's results, which is about half the density of lead. It is very extraordinary that this should agree so exactly with Newton's conjecture, *Principia*, lib. iii., prop. x.:—"Unde cum terra communis suprema quasi duplo gravior sit quam aqua, et paulo inferius in fodinis quasi triplo vel quadruplo aut etiam quintuplo gravior reperiatur: verisimile est quod copia materiæ totius in Terra quasi quintuplo vel sextuplo major sit quam si tota ex aqua constaret; præsertim cum Terram quasi quintuplo densiorem esse quam Jovem jam ante ostensum sit."

5. A short numerical calculation will now give us the *weight* of the Earth (Hamilton, "Lectures on Quaternions"); also of the Moon, Sun, &c.

We assume that the Earth is a sphere, whose girth is 40,000 kilometres, so that R, the radius of the Earth, is $10^7 \div \frac{1}{2}\pi$ m (metres), and the volume, V, is $\frac{4}{3}\pi\mathrm{R}^3$ m³, while the weight, E, is $\rho\mathrm{V}$ t (metric tonnes of 1000 kg, or 2205 lbs.), where $\rho = 5{\cdot}5$.

Four-figure logarithms will suffice for our calculations; and now

$$\begin{aligned}
\log 10^7 &= 7{\cdot}000\\
\log \tfrac{1}{2}\pi &= {\cdot}1961\\
\log \mathrm{R} &= 6{\cdot}8039, \quad \mathrm{R} = 10^6 \times 6{\cdot}366 \text{ m},\\
\log \mathrm{R}^3 &= 20{\cdot}4117\\
\log \tfrac{4}{3}\pi &= {\cdot}6221\\
\log \mathrm{V} &= 21{\cdot}0338, \quad \mathrm{V} = 10^{21} \times 1{\cdot}081 \text{ m}^3,\\
\log \rho &= {\cdot}7404\\
\log \mathrm{E} &= 21{\cdot}7742, \quad \mathrm{E} = 10^{21} \times 5{\cdot}946 \text{ t},
\end{aligned}$$

or 6×10^{21} metric tonnes in round numbers.

The weight of the Moon, M, generally taken as one-80th of the Earth, will be $10^{19} \times 7{\cdot}432$ t.

To determine S, the weight of the Sun, we employ Kepler's Third Law, which gives

$$\frac{\mathrm{S+E+M}}{\mathrm{E+M}} = \frac{n^2a^3}{n'^2a'^3},$$

where n, n' denote the mean motions of the Sun and Moon, and a, a' their mean distances from the Earth.

Since M is insignificant compared with E, and E compared with S, we may write this

$$\frac{\mathrm{S}}{\mathrm{E}} = \frac{n^2a^3}{n'^2a'^3},$$

where $n'/n = 13$, the number of lunations in a year, and $a/a' = 390$, the ratio of the mean distances of the Sun and the Moon, this being the ratio of 57′ to 8″·8, the inverse ratio of the parallaxes.

Now

$$\begin{aligned}
\log a/a' &= 2{\cdot}5911\\
\log (a/a')^3 &= 7{\cdot}7733\\
\log (n'/n)^2 &= 2{\cdot}2279\\
\log \mathrm{S/E} &= 5{\cdot}5454, \quad \mathrm{S/E} = 351{,}100;
\end{aligned}$$

so that the weight of the Sun is about 350,000 times the weight of the Earth, or about 2×10^{27} t, or 2×10^{33}g.

To determine the value of G the acceleration of gravity on the surface of the Sun, compared with g, the value on the surface of the Earth, we have

$$\frac{\mathrm{G}}{g} = \frac{\mathrm{S}}{\mathrm{E}}\left(\frac{\text{diameter of earth}}{\text{diameter of sun}}\right)^2 = \frac{\mathrm{S}}{\mathrm{E}}\left(\frac{8{\cdot}8}{960}\right)^2,$$

since the apparent semi-diameter of the Sun as seen from the Earth is about 960″, while the apparent semi-diameter of the Earth as seen from the Sun, in other words the solar parallax, is taken as 8″·8.

Now

$$\begin{aligned}
\log 960 &= 2{\cdot}9823\\
\log 8{\cdot}8 &= {\cdot}9445\\
\log (960 \div 8{\cdot}8) &= 2{\cdot}0378\\
\log (960 \div 8{\cdot}8)^2 &= 4{\cdot}0756\\
\log \mathrm{S/E} &= 5{\cdot}5454\\
\log \mathrm{G}/g &= 1{\cdot}4698, \quad \mathrm{G}/g = 29{\cdot}49.
\end{aligned}$$

6. According to Newton's Law of Universal Gravitation, the operation of weighing out the quantity W in the balance gives the same result wherever the operation is carried out in the universe, assuming that the balance and the body to be weighed are of ordinary moderate dimensions.

It is otherwise with the quantity denoted by P, because the magnitude of the gravitation unit of force varies, being proportional to the local value of g.

Suppose we write the first two equations

$$\mathrm{P}gs = \tfrac{1}{2}\mathrm{W}v^2, \quad \mathrm{P}gt = \mathrm{W}v,$$

and now put $\mathrm{P}g = \mathrm{Q}$; this is equivalent to taking a new unit of force, $1/g$th part of the former unit; this is an invariable unit.

Now our dynamical equations become

$$\mathrm{Q}s = \tfrac{1}{2}\mathrm{W}v^2, \quad \mathrm{Q}t = \mathrm{W}v,$$

from which g has disappeared.

The first suggestion of the change to this new absolute unit of force is due to Gauss, who found the necessity of it when comparing records of the Earth's magnetic force, made at different parts of the Earth's surface, and all expressed in the local gravitation unit.

It is curious that this suggestion of an absolute unit of force, the same for all the universe, did not originate with the astronomers; but Astronomy remains mere Kinematics until an accurate determination of the Gravitation Constant has been made.

On the F.P.S. (British foot-pound-second) system, this absolute unit of force is called the *poundal*, a name due to Prof. James Thomson; so that

$$\mathrm{Q}s = \tfrac{1}{2}\mathrm{W}v^2 \text{ (foot-poundals)}, \quad \mathrm{Q}t = \mathrm{W}v \text{ (second-poundals)}.$$

On the C.G.S. (Metric centimetre-gramme-second) system, this absolute unit of force is called the *dyne*, the centimetre-dyne of work being called the *erg*, and the second-dyne of impulse being called the *bole;* and now

$$\mathrm{Q}s = \tfrac{1}{2}\mathrm{W}v^2 \text{ (ergs)}, \quad \mathrm{Q}t = \mathrm{W}v \text{ (boles)}.$$

These absolute units are always employed in the statement of dynamical results in Electricity and Astronomy, where cosmopolitan interests are considered.

7. The disappearance of g from the dynamical equations is such a comfort to the algebraist, that he now makes a new start *ab initio* in dynamics, and gives a new definition of the absolute unit of force.

He defines the *poundal* as the force which, acting on a pound weight, makes the velocity grow one foot per second every second; and he defines the *dyne* as the force which, acting on a gramme weight, makes the velocity grow one centimetre per second every second; and now if W lbs. or g is acted upon by a force of Q poundals or dynes, the acceleration a is given by

$$a = \mathrm{Q/W} \text{ (}\textit{celoes}\text{ or }\textit{spouds}\text{)},$$

and

$$\mathrm{Q} = \mathrm{W}a,$$

leading to the original equations

$$\begin{aligned}
\mathrm{Q}s &= \tfrac{1}{2}\mathrm{W}v^2 \text{ (foot-poundals or ergs)},\\
\mathrm{Q}t &= \mathrm{W}v \text{ (second-poundals or boles)}.
\end{aligned}$$

These definitions of the absolute unit of force are very elegant and useful so long as we confine ourselves to calculations on paper, but they will not satisfy legal requirements. There is no apparatus in existence which will measure a *poundal* or *dyne* from these academic definitions within, say, 10 per cent. For accurate definition we must return to the old gravitation measure, and define the *poundal* or *dyne* as one-gth part of the force with which the Earth attracts a pound weight or a gramme weight, the value of g (in celoes or spouds) being determined by pendulum observations; and now the standard weight and the value of g are capable of measurement to within, say, one-100th per cent., an accuracy sufficient to prevent litigation.

In the recent report of the Committee on Electrical Standards we find the *ohm* defined as the equivalent of a velocity of ten million metres (one quadrant of the Earth) per second, to satisfy theoretical requirements; but as this definition would be useless for commercial purposes, Dr. Hopkinson insisted that it was essential that an alternate definition should be given, legalizing certain bars of metal as standard ohms.

In converting absolute and gravitation measure, we must notice that there are, strictly speaking, three different g's in existence: (1) the g of pure gravity of a body falling freely; (2) the g determined by a plumb-line, or by a Foucault pendulum of which the plane of oscillation is free to rotate; (3) the g determined by a pendulum oscillating in a fixed vertical plane, about a fixed axis; this is the legal g, so to speak, although practically undistinguishable from the g given in (2).

Sir W. Thomson's Standard Electrical Balance Instruments are graduated in gravitation measure, so that, if calibrated at Glasgow, they are one-25th per cent. in error in London, and about one-7th per cent. in error at the equator, and a corresponding correction imust be made.

An absolute Spring Balance instrument would possess a spurious absoluteness, in consequence of the deterioration of temper of the spring, and of its variation of strength with the temperature, as experienced in the Indicator.

8. There is no advantage or gain of simplicity by the use of absolute units in dynamical questions concerning motion which is due to the gravitational field of force; the only change being the removal of g from the denominator on the right hand side of our dynamical equations to the numerator on the left-hand side.

For this reason engineers and practical men invariably employ the gravitation unit of force in the dynamical questions which concern them; measuring, for instance, their forces in pounds, pressures in pounds per square foot or square inch, while at the same time measuring the quantity of matter in the moving parts by pound weights.

The absolute unit of force has only recently made its way into dynamical treatment, principally in consequence of the development of Electricity. Previously the gravitation unit was universally employed, with the consequence that W in the equations of motion always appeared qualified by a denominator g, in the form W/g.

9. Noticing that W never appeared alone, but always as $\frac{W}{g}$ (for instance, that if a celoes is the acceleration which a force of P pounds causes in a weight of W lbs., then

$$P = \frac{W}{g}a, \text{ or } a = \frac{P}{\frac{W}{g}}\Big),$$

early writers on Dynamics were unfortunately tempted to make an abbreviation in writing and printing, by replacing $\frac{W}{g}$ by a single letter M; so that the dynamical equations could be printed

$$P = Ma \text{ (pounds)},$$
$$Ps = \tfrac{1}{2}Mv^2 \text{ (foot-pounds)},$$
$$Pt = Mv \text{ (second-pounds)},$$

each occupying one line of print.

This quantity M was variously called the *mass* of the body—a quantity *sui generis*—the *massiveness* of the body, the *inertia*, or the *invariable quantity of matter* in the body.

But if M denotes the invariable quantity of matter, we have this awkwardness, that M, the invariable quantity, is measured in terms of a variable unit, g pounds; while the force P, which varies with g, is always measured by means of a definite lump of metal, the pound weight.

This awkwardness is rectified if we change the unit of force, and measure P in absolute units, poundals, and M in lbs., but now M becomes the same as W, formerly; and its introduction only causes confusion, because M is still taken by most writers on Dynamics as defined by

$$M = \frac{W}{g};$$

thus making $W = Mg$, the source of all the confusion in our dynamical equations.

If weight W is measured in pounds, as the Act of Parliament directs, and if the unit of mass is one pound, so that M is also measured in pounds, then, if W and M refer to the same body, W = M, and not Mg.

If $W = Mg$, and W is measured in lbs., then M is measured in units of g lbs., a variable unit, unsuitable for a cosmopolitan question.

But if $W = Mg$, and M is measured in pounds, then weight W is measured in units of one-gth part of a pound, or *poundals*, which is illegal according to the Act on Weights and Measures, c. 19, 41 and 42 Victoria: "Any person who sells by any denomination of weight or measure other than one of the imperial weights or measures, or some multiple or part thereof, shall be liable to a fine not exceeding forty shillings for each such sale."

10. The theoretical writer overrides these difficulties by giving a new definition of Weight, not contemplated or mentioned in the Act of Parliament:

"The weight of a body is the force with which it is attracted by the Earth."

Let us examine this definition closely.

In the first place, it does not appear to contemplate the use of the word *weight*, except in reference to bodies on or near the surface of the Earth.

According to this definition, what is the weight of the Moon, or of a body on the Moon? Must the Moon be brought up to the surface of the Earth in fragments, or must the weight be estimated at the present distance of the Moon?

What, again, is the weight of the Sun, or of a body on the Sun? and what is the weight of the Earth itself?

And what does Sir Robert Ball mean when he writes that "the weight of Algol is about double the weight of the Sun"?

Considering, however, merely bodies of moderate size on the surface of the Earth, the attraction of pure gravity of the Earth is only to be found in a body falling freely; the tension of a thread by which a body is supported is influenced by the rotation of the Earth.

Again, the local value of g is, theoretically speaking, influenced by the position of the Moon and Sun; it is true that the influence is insensible on the plumb-line, although manifest on such a gigantic scale in its tide-producing effects.

Suppose, then, we employ the gravitation unit of force in the theorist's definition of the weight of a body. The definition now becomes an inexact truism asserting that the Earth attracts W lbs. with a force of W pounds, and inexact, because it neglects the discount in g due to the rotation of the Earth; and to say that "the weight of a body is the force with which it is attracted by the Earth" conveys no additional information.

Having introduced the word *mass*, primarily as a mere abbreviation in printing, and having subsequently changed the unit of mass so as to make the mass the same as the weight, the theorist is now trying to dislodge the word *weight* from its primary meaning, which it has possessed for thousands of years, as meaning the quantity of matter in a body, and is trying to degrade it into a subsidiary position, to express a mere secondary idea, the attraction of gravity; and that only on the surface of the earth, and even then not clearly defined.

We might as well define the pound sterling by its purchasing power in any locality, instead of by its proper definition as a certain quantity of gold.

11. So long as the gravitation unit of force alone was employed, the same number, which expressed the number of the weights which equilibrate the body, also expressed the number of pounds of force with which the Earth appeared to attract the body; and it is only in this sense that the weight of a body is "the force with which it is attracted by the Earth"; it is essential that the unit of force should be the gravitation unit, when this definition is employed.

We say, for instance, in Hydrostatics, that a ship is buoyed up by the water with a force equal to the weight of the displaced water, which is also equal to the weight of the ship, when in equilibrium.

Again, the head of water which will produce a pressure of 150 lbs. on the sq. inch, is always

$$150 \times 144 \div 62{\cdot}5 = 345{\cdot}6 \text{ feet},$$

whatever the local value of g; the numerical measure is always the same, although the amount may differ in consequence of the variation of g and the unit of force. A boiler tested to 150 lbs. on the square inch is tried one-25th per cent. more severely in Glasgow than in London. This variation, at most ½ per cent., is not likely to lead to litigation—*De minimis non curat lex.*

There is no particular harm in the use of the word *mass*, provided it is always measured in the standard units of weight; there is this drawback, that there is no verb to "mass"; we can say that the body weighs W lbs., but we cannot say it "masses" M lbs.

Again, the Acts of Parliament do not regulate "Masses and Measures," but "Weights and Measures," "Poids et Mesures," "Maasse und Gewichte," "De Ponderibus et Mensuris."

The French language possesses the two words *Poids* and *Pesanteur*, both of which we translate by Weight.

Poids may be translated *mass*, or quantity of matter, *copia materiæ;* but that does not justify the degradation of *weight* down to the meaning of *pesanteur*, and that merely the *pesanteur* on the surface of the Earth; having already invented *mass*, the theorist must invent a new word to translate *pesanteur;* the word *heft* has been suggested, but the word *weight* must be left alone, to do double duty occasionally.

A libellous story of the Hudson Bay Company says that in their former dealings with the Red Indians, the weight of the factor's fist was always one pound; a good illustration of weight as meaning both *poids* and *pesanteur* to ignorant minds.

An amusing instance of the confusion of using *weight* in the double sense of *poids* and *pesanteur*, when not restricted to the provincial gravitation unit of the surface of the Earth, on which the human race is imprisoned, occurred in a lecture last year on Popular Astronomy. To illustrate the fact that g on the surface of the Sun is about 30 times greater than it is here (§ 5), the lecturer said, "An ordinary middle-aged man of this audience, if transported to the surface of the Sun, would *weigh about two tons;* but his reflections on this difficulty would be cut short by the immediate prospect of being converted into *two tons of fuel.*"

12. Maxwell unfortunately lent his powerful aid to the attempt to degrade the word *weight* to mean merely *pesanteur.*

In a review of Whewell's "Writings and Correspondence," edited by Todhunter, Maxwell writes that—

"Finding the word weight employed in ordinary language to denote the quantity of matter in a body, though in scientific language it denotes the tendency of that body to move downwards, and at the same time supposing that the word mass in its scientific sense was not sufficiently established to be used without danger in ordinary language, Dr. Whewell endeavoured to make the word weight carry the meaning of the word mass. Thus he tells us that—the weight of the whole compound must be equal to the weight of the separate elements."

"It is evident that what Dr. Whewell should have said was—the mass of the whole compound must be equal to the sum of the masses of the separate elements."

But Whewell was quite right, because, at the time he wrote, mass was merely the printer's abbreviation for

$$\frac{W}{g}.$$

"We are reminded by Mr. Todhunter that the method of comparing quantities by weighing them is not strictly correct." (Compare this statement of Todhunter with that of Dr. Harkness in his article on "The Art of Weighing and Measuring," NATURE, August 15, 1889, p. 381, where it is pointed out that weighings can be carried out to within one 10-millionth part.)

Again, in Maxwell's "Theory of Heat" (p. 85), we read "In a rude age, before the invention of means for overcoming friction, the weight of bodies formed the chief obstacle to setting them in motion. It was only after some progress had been made in the art of throwing missiles, and in the use of wheel-carriages and floating vessels, that men's minds became practically impressed with the idea of mass as distinguished from weight. Accordingly, while almost all the metaphysicians who discussed the qualities of matter, assigned a prominent place to *weight* among the primary qualities, few or none of them perceived that the sole unalterable property of matter is its *mass.*"

The question in dispute resolves itself, then, merely into a difference of terminology; and the metaphysicians are using the language universally employed up to the middle of this century, and are justified on all sides in their usuage: Maxwell might as well have criticized the traditional names which astronomers employ for the heavenly bodies.

Maxwell would even have edited the authorized and revised version of the New Testament; in *ὡσεὶ λίτρας ἑκατόν*—translated "about an hundred pound *weight*"—(John xix. 39), he proposed the omission of *weight*, probably inserted in the version to make a distinction from pounds *sterling*.

This addition of the word weight is common elsewhere, thus, "His Majesty's Warrant, August 19, 1683, to cause 3 barrels of fine pistol powder, 3 cwt. weight of pistol bullets, and 3 cwt. weight of match to be delivered to John Leake, Master Gunner, for the use of the 3 troops of Granadiers, &c." ("Notes on the Early History of the Royal Regiment of Artillery," by Colonel Cleaveland).

Dr. Lodge says that the term hundredweight bears marks of confusion on its surface, and had better be avoided; what does he say to this use of hundredweight weights, not intended to mean pull of gravity?

This Warrant is dated four years before the first edition of the "Principia," in which the downward tendency of a weight was first clearly demonstrated as due to the attraction of the Earth, although mere surmises had been propounded by early astronomers, and in "Troilus and Cressida" we have—"As the very centre of the earth, drawing all things to it."

But Acts of Parliament on "Weights and Measures" were extant hundreds of years before the first appearance of the "Principia"; and when the standard pound weight was defined in these Acts, it was the lump of metal preserved at the Exchequer that was described, and not the pressure on the bottom of the box in which it was kept.

13. Formerly, the words *vis inertiæ*, or *inertia*, were used instead of the modern word *mass* (often used in ordinary language as the equivalent of *bulk*). But it is useful to notice that inertia is not always the same thing as weight or mass, or even proportional to them.

Thus the inertia of a body is increased by the presence of the surrounding medium; the inertia of a sphere moving in a frictionless incompressible liquid is increased by half the weight of the liquid displaced, and of a cylinder moving perpendicular to the axis by the weight displaced; while an elongated projectile requires rotation about an axis for stability of flight, in consequence of its inertia being different for different directions of motion.

The inertia of a pendulum, or of the train in § 2, is increased to an appreciable extent by the presence of the surrounding air.

Again, the inertia of a rolling hoop is twice its weight, of a cylinder is half again as great, of a billiard ball is 40 per cent. greater; and the inertia of a bicycle, or of the train we have considered in § 2, when the *rotary inertia* of the wheels is taken into account, must be increased by a fraction of the weight of the wheels and axles equal to k^2/a^2, where a is the radius of a pair of wheels, and k the radius of gyration of the wheels and axle about the axis of rotation.

For the same reason the centre of inertia does not always coincide with the centre of gravity, or centre of mass. The buffers of a railway carriage should be at the height of the centre of inertia; and this is easily seen to be at a height

$$h \bigg/ \left(1 + \frac{w}{W}\frac{k^2}{a^2}\right)$$

above the axles, w denoting the weight of the wheels, W of the body of the carriage, and h the height of its centre of gravity above the axles.

The recommendations of the A.I.G.T., in their "Syllabus of Elementary Dynamics," will only serve to widen the increasing gulf between theoretical treatises and the Applied Mechanics which engineers use, unless the Committee of the A.I.G.T. will set to work to invent a totally new word, such as *heft*, to express the pull of gravity on a given weight, as an equivalent of the French word *pesanteur*; it is hopeless to attempt todegrade the, old word *weight* into the subsidiary secondary meaning so long as in commerce, and in the Acts of Parliament, *weight* invariably means quantity of matter, *copia materiæ*.

A. G. GREENHILL.

APHANAPTERYX AND OTHER REMAINS IN THE CHATHAM ISLANDS.

In a former letter I sent you some account of the finding of the *Aphanapteryx* in the Chatham Islands. I have now gone more carefully over the bones I collected there, and some additional notes may not be without interest. I find that, of the heads I have obtained, a number are much larger than that of *Aphanapteryx broeckei* (Schlegel), and are therefore rightly assigned, I think, to a distinct species. The tarso-metatarsus, as figured by M. Milne-Edwards, however, may, I think, prove to belong not to *Aphanapteryx*, or at any rate not to a species with so robust a tibia. I found several tarso-metatarsi in near relation to the tibiæ and femora, and heads of *A. hawkinsi*, and they are all without exception much shorter and stouter bones in proportion to the tibiæ and femora. Out of the same strata which contained *Aphanapteryx*, I obtained a number of the bones of the skeleton of a *Fulica* very nearly related to *F. newtoni*. Like the *Aphanapteryx* bones, they vary very much in size, some being equal, others much larger than those of *F. newtoni*. So much so that I am inclined to recognize them as different species, or at least different races. The larger species I have named *F. chathamensis*. The portions I have had before me are the pelvis, the femur, the tibia, and metatarsus. I have portions of a large ralline skull, which may be that of this *Fulica*, but it is rather too imperfect to enable me to speak more confidently at present. The tarso-metatarsi of this bird agree much more closely with the tarso-metatarsus assigned in M. Milne-Edwards's plate to *Aphanapteryx*. Of the *Aphanapteryx* I possess the complete cranium, femur, tibia, metatarsus, humerus, and pelvis. Among the other interesting specimens so far identified, are the humeri and pelvis of a species of Crow half as large again as *C. cornix*. They agree closely with those of a true *Corvus*. I have designated it as *Corvus moriorum*, as I found some of these bones among the remains scattered round a very ancient Moriori cooking-place, which had become uncovered by the wind in the strata in which *Aphanapteryx* occurs. Indeed, in this kitchen-midden I gathered portions of the *Aphanapteryx*, of a large swan, of several species of ducks, and of a *Carpophaga* indistinguishable from the species now living on the islands—a species (*Carpophaga chathamica* mihi[1]) new to science. I may say that it is easily distinguished from *C. novæ-zealandiæ* by the breast-shield in both sexes being altogether duller than, and not extending so far ventrally as, in the latter. The head, neck, and breast are of the same colour—a dull green, with purple and green metallic reflections when viewed with the bird between the light and the eye. It is, however, most markedly distinguished by the pale lavender colour of the external border of the wings, the much paler colour of the lower back and rump, and by the black on the under surface of the tail feathers being prominent on all the rectrices except on the anterior portions of the outer tail feather on each side, and passing under the tail coverts in a broad wedge. Mr. Travers relates that he was informed by one of the early settlers on Pitt Island that he remembered the first appearance of the pigeon in the islands. This statement cannot well be accepted in face of the presence of the bird's bones in a midden so ancient as that I have referred to above. In the *Aphanapteryx* beds, I obtained also the portions of a skull of a species of *Columbidæ*, apparently of a *Columba*, of which I can say little till I am in possession of more material. I have obtained also bones of the small hawk (*Harpa*), showing that it existed on the islands, whereas it is now unknown there, although *Circus gouldi* is not uncommon.

At about 3 feet below the floor of a small cave, which the weathering limestone has deposited, I obtained portions of a pigmy Weka (*Ocydromus pygmæus*), and also the limb bones of a rat. If they have been gradually covered to this depth by the fall of particles from the roof, as there seems no reason to doubt, their age must be very great; but whether that would take us back to a date antecedent to the arrival of the Morioris in the Chatham Islands is a more difficult question to answer with our present data.

So far, the birds of whose presence in the Chatham Islands till now we have had no knowlege, are: *Harpa ? ferox*, *Nestor meridionalis* and *? N. notabilis*, *Corvus*

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[1] ? *Carpophaga chathamensis* of Rothschild, P.Z.S. 1891, p. 312, pl. xxviii.—Ed.]